

# Learning Pedagogy in Physics

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**Abstract.** We report on an adapted version of the Physics and Everyday Thinking (PET) curriculum. A unique aspect of PET is its inclusion of special activities that focus on Learning about Learning (LAL) in which undergraduates analyze videos of children talking about science and explicitly consider the nature of science. To create a course that intentionally linked science content, children's ideas, and strategies for science instruction, we augmented the existing LAL activities with discussions about teaching, and added activities focused on LAL from companion curricula such as Physical Science and Everyday Thinking (PSET) and Learning Physical Science (LEPS). To compensate for the additional time on LAL, we reduced the content activities to only those that directly supported LAL activities. We found that students made significant gains on the CLASS and expressed beliefs about teaching consistent with the PET pedagogy.

**Keywords:** Teacher Education, Pre-service Training, Curriculum Design, Physics Education Research

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## INTRODUCTION

The National Task Force on Teacher Education in Physics recently expressed concern about the state of teacher training for high school physics teachers [1] and U.S. elementary school teachers report low levels of science content knowledge and a lack of confidence in their ability to teach science. [2] Clearly, greater attention to the training of science teachers at all levels is necessary. [3] Here we report on the development and field test of a course in which physics was a vehicle for students to learn about teaching.

In the National Science Education Standards and related documents, the National Research council recommends that science be taught through methods consistent with scientific inquiry. [4] However, many teachers do not have sophisticated understandings of how science knowledge is generated through inquiry. [5-7] One aspect of scientific inquiry that is particularly difficult for students to understand is process of proposing, testing, and revising models to explain science phenomenon.

Models, broadly defined are representations of how some aspect of the world works (e.g., magnetism, the atom). [8] Scientific models can take many forms such as physical representations, drawings, analogies, and computer simulations. A good model has both explanatory and predictive power. Models or representations are proposed and tested through the

collection of additional evidence. If predictions guided by the model are confirmed, the model gains more credence. If the predictions are disconfirmed, the model is revised.

Engaging students in the practice of developing and revising modeling has been found to be an effective strategy for teaching science [9] that even young children can engage in. [10] However, it is a strategy that is rarely observed in K-12 science instruction. [11] Even a sophisticated understanding of modeling may be insufficient for being about to teach science through model-based instructional methods. To engage students in developing, testing, and revising models, teachers must be able to identify an appropriate phenomenon, elicit students' initial models and suggest or guide students to an appropriate test of their model.

To teach science well, teachers need to not only develop science content knowledge, but they also need to develop understandings and attitudes about students and learning. Moreover, they need to integrate these different kinds of knowledge into a coherent base that they can access and use effectively when teaching. [12] Developing and integrating knowledge of science content, teaching and learning may be complicated by the structure of teacher education programs. Pre-service teachers typically learn science content in science courses offered by physics, biology or chemistry departments and learn about teaching and learning in education and psychology departments.

Learning about teaching and learning *while* learning science content may be beneficial for pre-service teachers. Further, it is well documented that teachers use the same methods of instruction as those used in the courses they were students in. [13] Providing the opportunity for pre-service teachers to learn science through inquiry may increase the likelihood that they will use similar methods in their future instruction.

With this in mind, we desired to develop a course that provided pre-service teachers with the opportunity to learn science through model-based instruction. We also intentionally designed the course to help teachers develop and integrate ideas about inquiry, teaching strategies for inquiry, and children's ideas. Below, we describe this process and the preliminary research associated with the course.

## CONTEXT AND METHODS

### Physics and Everyday Thinking (PET)

We began with the *Physics and Everyday Thinking* (PET) [14] curriculum as a foundation for creating a course referred to here as *Physics for Teaching*, which focused on learning about teaching through inquiry. This class was intended for prospective secondary science teachers with non-physics backgrounds and for prospective elementary teachers.

PET was selected as the basis of this course because content is learned through guided inquiry and because special activities are included that help undergraduates think about learning. These activities, called Learning about Learning (LAL) activities, involve analyzing children's ideas, explicit instruction on the nature of science and reflecting on the relationship between the nature of science and the process of learning science. While the explicit focus on the nature of learning and nature of science are an important component of PET, it should be noted that the primary goal of PET is learning physics content. This priority of learning goals is a significant difference between PET and *Physics for Teaching*.

Previous work found that in-service teachers who take PET sometimes try to use PET activities in their elementary classrooms without considering their own students' ideas and how the activities will or will not impact the elementary students' ideas. [15] For example, the model of magnetism series of activities in PET is built on the expectation that undergraduate students will propose a particular initial model of magnetism (the charge separation model of magnetism) [16]; the subsequent activities provide evidence that conflicts with this assumed model and prompts revision. By the end of the unit,

undergraduates typically arrive at a domain-like model of magnetism. Children, however, do not tend to propose this same initial model and yet elementary teachers have been observed proposing the same test used to challenge the adults' model. The test used in PET (predicting what would happen if a magnetized nail is cut in half) does not lead to conflicting evidence for typical models proposed by children and thus does not prompt revision.

That the teachers attempted to apply what they learned in PET to their instruction is a positive outcome. However, these observations suggest that these inservice teachers who participated in PET may not have understood the underlying knowledge that led to the development of PET activities. In particular, PET inservice teachers were not aware that the developers anticipated a particular model based on research on undergraduate's ideas about magnetism and designed an activity to challenge this particular idea. This finding is not surprising since curricular decisions are often hidden from students. [17] Nor is it problematic if the primary goal is for students to learn physics content. Making curricular decisions visible to inservice teachers and undergraduates who may become teachers is important, however.

### Research Design

We hypothesized that learning through developing models and explicit reflection on the design and expected prior knowledge and research on learning that led to curricular design decisions would be beneficial to undergraduates considering a career in teaching. Specifically, such instruction might help them develop understandings about how students learn through the process of model based instruction and develop ideas about how to facilitate this process, even before beginning a teacher education program.

#### *Modifications to PET and the Learning Context*

We made three primary modifications to PET. First, we increased time on Learning about Learning (LAL) activities. The PET curriculum contains 47.6 hours of class time dedicated to physics content and 4.9 class hours dedicated to LAL. Since the LAL activities were directly related to our primary goals, we increased time spend on LAL through extended discussions on existing LAL activities and supplementing with LAL activities from similar curricula [e.g., 18-19]. In addition, we added questions about instructional strategies, which is not an explicit part of PET. That is, after nearly every LAL activity that involved videos of children learning science, we discussed what the undergraduates would do next if

they were the elementary school teacher. To account for the additional time on LAL and only 24 hours of contact time, we reduced physics content to only activities that directly supported the LAL activities. Content learning was used to reflect on and support undergraduates' analysis of children's ideas and to build an understanding of inquiry. Our adapted version resulted in 13.7 hours of content instruction and 10.4 hours of LAL.

Second, we changed the order of the curriculum. We began with Unit 4, the model of magnetism. The Model of Magnetism series of activities is the most extensive model-building unit. Students develop a domain-like model of magnetism through proposing tentative models and iteratively revising them as they test their models against additional evidence. Beginning with this unit allowed us to establish modeling both as an example of the scientific process and as an example of an instructional method that we could refer to throughout the course. The magnetism unit was followed by units on energy, forces, and electricity. The light unit was omitted due to a lack of time.

Finally, we added a series of assignments focused on teaching. These included an initial assignment in which undergraduates listed what they thought a teacher needed to know about children, science content, and teaching in order to teach science well. This was intended to get an initial sense of the undergraduates' ideas about what constituted knowledge for teaching. Undergraduates completed similar assignments specific to the content areas of magnetism and force and motion. In place of a final exam, undergraduates developed and presented science lessons that followed the pedagogy of PET but were intended for elementary school. They were instructed to draw on aspects of modeling as an instructional strategy in designing their lesson plan.

#### *Data Collection and Analysis*

Participants included 22 upper division college students from a range of majors (6 majoring in math or science). Two video cameras were used to film the entire course. Each camera was assigned to a particular tracer student who was filmed each day along with his or her group that day. The tracer students were selected based on an initial survey on their comfort level with science and their career aspirations. One tracer student, Clark, was a prospective high school computer science teacher. The other tracer student, Alice, was a prospective elementary school teacher. If the tracer student was absent on a particular day, an alternate was selected who met similar criteria. Both video cameras filmed whole class discussions. Data also included interviews with 5 focus students, pre and

post Colorado Learning Attitudes about Science Survey (CLASS) [20] responses, pre and post ideas about learning survey, weekly online responses which focused on teaching and learning, and homework assignments that were specifically designed for this course. Transcripts of observations and interviews were coded according to statements about teaching and statements about children. Sub-codes within these general categories were emergent. At least two independent coders coded all of the data; disagreements were resolved through discussion. Findings and evidence presented here come only from video recordings of class discussions and from the CLASS.

## **FINDINGS**

During the final class period, we discussed how the similarities and differences between the Physics for Teaching course and their other science courses and whether they thought this was an appropriate method for teaching elementary school children. In general, students appreciated learning physics through inquiry and felt it was more effective for their own learning than more traditional methods. For example, one undergraduate talking about what she learned in Physics for Teaching stated, "These are really basic [physics] concepts and I feel like I really didn't remember. I've learned all this in high school and it didn't stick, but if I'd done these experiments [that we did in class], I would have remembered the experiments. It would have been something that stood out in my mind." These types of statements were typical throughout the course.

At the end of the course, however, undergraduates were divided on whether it would be appropriate to apply the instructional method of modeling to the teaching of elementary school children. One student argued that text-based instruction was preferable because of the lack of time devoted to elementary school science, "I think that we do need to learn text-based science first because it's quicker. Elementary teachers don't have a lot of time for science so you kind of need to get to the point, to the answers." She continued, "But I think it's more beneficial for the students to learn in the way that we're learning. I think in a perfect world it would be great but we don't have that much time."

The undergraduates' ability to *apply* ideas about inquiry to K-5 education were also mixed. Following activities in which we watched videos of children who expressed ideas that were not consistent with scientific ideas, class discussions focused on what the undergraduates would do next if they were the classroom teacher. In these discussions, groups tended

to propose methods of helping the child test his ideas in ways that would provide evidence that would prompt him to revise his ideas. In contrast, the final projects did not show strong evidence of their ability to apply model-based methods of instruction to the larger task of developing a full lesson. The activities they developed tended to involve hands-on aspects and used pedagogical techniques used in the course (eliciting ideas and asking guiding questions). But, the lessons they developed did not build on or test the ideas elicited.

Because the CLASS focuses on attitudes about learning science, the results of this assessment are also of interest. One would expect that instruction focused on teaching and learning science would lead to gains. Indeed, undergraduates made an average gain of 14.0 on the CLASS. Results for introductory physics typically show changes between -9.8 to +1.4 in algebra-based physics for non-science majors and pre-med students [21]. This means that, in many courses, the students shift to a more novice view. The results from *Physics for Teaching*, however, are not atypical of gains in other PET courses. [22] As a whole, the undergraduates reported more sophisticated responses for almost every question asked. The exception was for the questions about mathematical aspects of physics. Likely, gains were due to the explicit attention to the nature of science and learning in the course.

## DISCUSSION

Traditionally undergraduates preparing to be teachers learn about topics such as how to elicit and identify children's ideas and strategies for teaching children in methods courses, disconnected from the content they will be teaching and from the experience of learning that content. Additional research is necessary to see if students who learn about teaching and learning in parallel with physics content go on to integrate knowledge of teaching, learning, and content into a coherent knowledge base that is usable for teaching. However, the preliminary results of this study are promising. Even though they found the implementation of model-based instructional techniques challenging, the undergraduates articulated an appreciation of such instructional methods. Explicit instruction about teaching and learning in content courses may allow prospective teachers to consider how the courses that they are learning science content in are designed to promote their own learning. A deeper understanding of the design decisions made by curriculum developers may help future teachers make

more informed decisions when they are later designing lessons for their own students.

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